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ELECTRODEPOSITED ZINC-NICKEL AS AN ALTERNATIVE TO CADMIUM PLATING FOR AEROSPACE APPLICATION

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Corrosion evaluation studies were conducted on 4130 alloy steel samples coated with electrodeposited zinc-nickel and samples coated with electrodeposited cadmium. The zinc-nickel was deposited by the selectron electrochemical metallizing process. These coated samples were exposed to a 5-percent salt fog environment at 35±2 °C (95±5 °F). The exposure period ranged from 96 to 240 hours. An evaluation of the effect of dichromate coatings on the performance of each plating was conducted. The protection afforded by platings with a dichromate seal was compared to platings without the seal. During the later stages of testing, deposit adhesion and potential for hydrogen entrapment were also evaluated.

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Corrosion Protection, Cadmium Plating, Electrodeposited Zinc-Nickel, Salt Fog Environment, Selectron Electrochemical Metallizing

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TECHNICAL MEMORANDUM

ELECTRODEPOSITED ZINC-NICKEL AS AN ALTERNATIVE TO CADMIUM PLATING FOR AEROSPACE APPLICATION

INTRODUCTION

Cadmium is a relatively rare metallic element which is recovered as a by-product of zinc refining operations. Cadmium coatings are utilized in applications where good corrosion resistance, especially saltwater corrosion resistance, low coefficient of friction, and a low electrical contact resistance are needed. Cadmium coatings are usually selected because they exhibit the best combination of properties and not just a simple property alone. However, disadvantages such as solid and liquid metal embrittlement of high strength steels and concerns about occupational health have created a need for alternatives. The objective of this test program was to evaluate electrodeposited zinc-nickel as an alternative to cadmium plating for aerospace application.

EXPERIMENTAL PROCEDURES

Testing was divided into three phases. Phase I, entitled Corrosion Testing, evaluates the corrosion protection afforded by electrodeposited zinc-nickel and by cadmium in a salt atmosphere. Phase II illustrates the adhesion strength of electrodeposited zinc-nickel. Phase III investigates the potential for hydrogen entrapment during the zinc-nickel electrodeposition process.

Phase I – Corrosion Testing

Test samples were constructed from 4130 alloy steel panels measuring 2 by 4 by 1/16 inches. Each panel was cleaned in accordance with Federal Specification TT-C-490. Each panel was coated with one of the following coating systems:

a. Electrodeposited zinc-nickel per MIL-P-85748 with a dichromate seal.

b. Electrodeposited zinc-nickel per MIL-P-85748 without a dichromate seal.

c. Electrodeposited cadmium per Federal Specification QQ-P-416 with a dichromate seal.

d. Electrodeposited cadmium per Federal Specification QQ-P-416 without a dichromate seal.

Test samples were exposed to a 5-percent salt fog environment at 35±2 °C (95±5 °F). The exposure period ranged from 96 to 240 hours. At the conclusion of the exposure period, the test samples were removed and inspected for corrosion.

Phase II – Adhesion

4130 alloy steel panels identical in size to Phase I panels were coated with electrodeposited zinc-nickel per MIL-P-85748. To illustrate the adhesion of the electrodeposit, bend tests were performed on several test panels, as shown in Figure 1.

Phase III – Hydrogen Entrapment

Bare and zinc-nickel coated 4130 alloy steel samples were exposed to the following environmental conditions:

a. No heat exposure

b. 176.8±4 °C (350±25 °F) – 1 hour

c. 176.8±4 °C (350±25 °F) – 3 hours

d. 176.8±4 °C (350±25 °F) – 24 hours.

The hydrogen content of each sample was then determined by combustion analysis.

RESULTS AND DISCUSSION

Figure 2 illustrates the general appearance of electrodeposited cadmium both with and without a dichromate seal. The normal appearance of cadmium is silver gray. However, the application of a dichromate seal changes the color to bronze gold. Figure 3 illustrates the general appearance of electrodeposited zinc-nickel with and without a dichromate seal. The normal deposit characteristic is smooth with a matte gray color. Application of a dichromate seal changes the color to olive green.

Figures 4a and 4b illustrate the corrosion protection afforded by cadmium plating after 96 and 240 hours of exposure to a salt fog environment. After 96 hours, no corrosion was present. However, stains were visible on each sample indicating the breakdown of the protective qualities of the coating. The sample without the dichromate seal was most adversely affected. After 240 hours of exposure, corrosion was visible on the sample without dichromate sealing. The sample with dichromate sealing exhibited severe staining, but no corrosion.

Figure 5 illustrates the corrosion-inhibiting properties of electrodeposited zinc-nickel both with and without a dichromate seal. After 96 hours of exposure, no corrosion or staining was present on dichromate sealed samples. The samples without dichromate sealing exhibited staining and a white corrosion product. However, the base metal was not attacked. After 240 hours of exposure, all of the samples exhibited staining and a white corrosion product, as shown in Figure 6. Again, the base metal was not attacked. Electrodeposited zinc-nickel provides protection not only by preventing the environment from contacting the surface of the steel, but also galvanically protecting the steel at damaged areas. In addition, since the zinc corrosion products are alkaline, they tend to provide supplementary protection by neutralizing the acidity of moisture condensing on the surface.

During Phase II of the test program, the bend test was utilized to illustrate the superior bond strength of electrodeposited zinc-nickel, as shown in Figure 1. There was no indication of plating debond or flaking from the base metal.

Phase III of the test program evaluates the potential for hydrogen entrapment by the zinc-nickel electrodeposition process. As plated, zinc-nickel samples measured an average increase of 4.8 ppm hydrogen over bare 4130 alloy steel samples as shown in Table 1. Upon exposure to 176.8 °C (350 °F) for 1 and 3 hours, the average difference in hydrogen content, between bare samples and zinc-nickel plated samples, was 10.15 and 10.2 ppm, respectively. After 24 hours of exposure, the average difference in hydrogen content was 3.25 ppm.

CONCLUSION

The results of these series of tests clearly indicate that electrodeposited zinc-nickel affords excellent corrosion protection to steel and ferrous metals in marine environments.

Protection is afforded by preventing the environment from contacting the base metal, but also galvanically at damaged areas. Test data clearly indicate that corrosion protection is enhanced by use of dichromate treatments. The process affords excellent adhesion as illustrated in Figure 1, and hydrogen entrapment by the process is minimal requiring little or no baking. These factors combined with a melting point of 419 °C (786 °F) or greater, as shown in Table 2, clearly indicate that electrodeposited zinc-nickel is a viable alternative to cadmium plating for aerospace application.

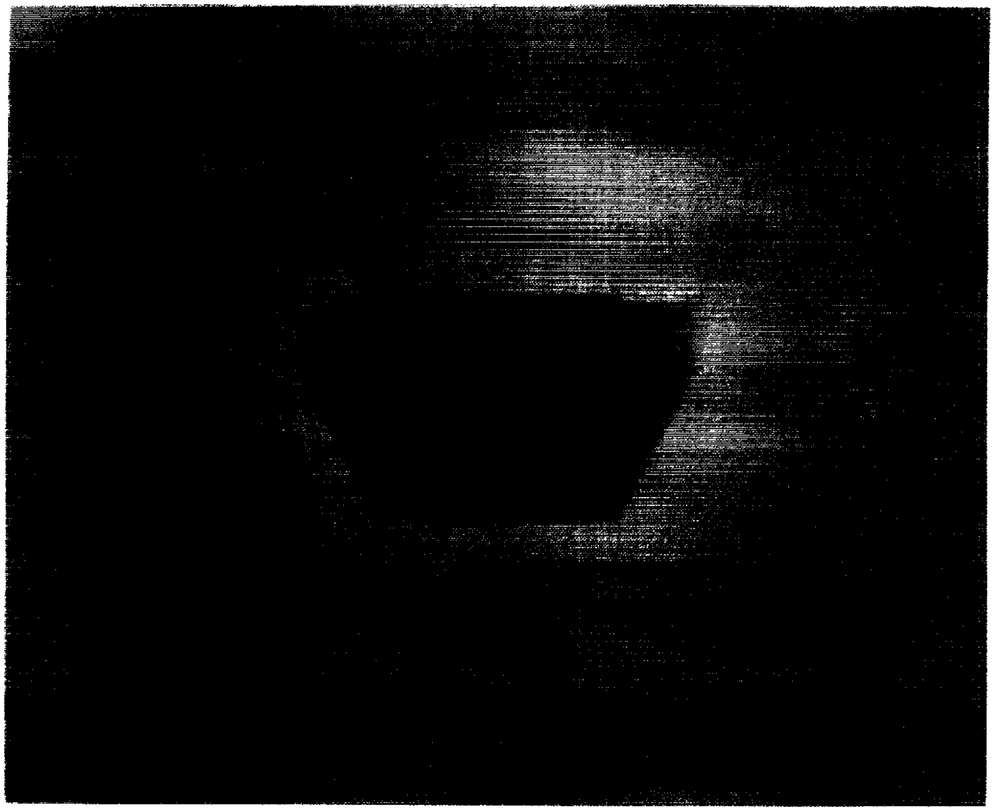


Figure 1. 4130 Steel Panel With Electrodeposited Zinc-Nickel Coating Illustrating the Effects of a Bend Test.

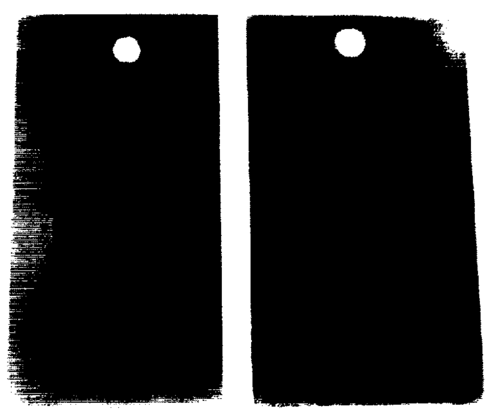
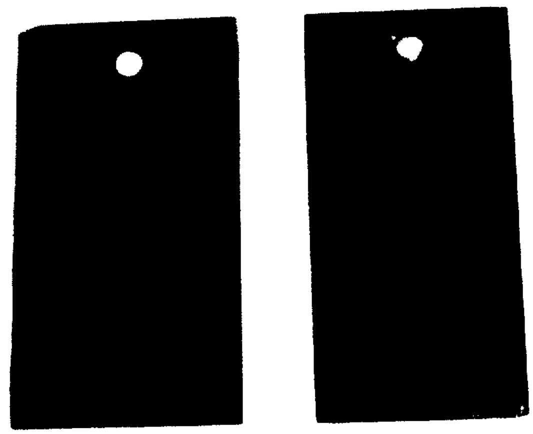
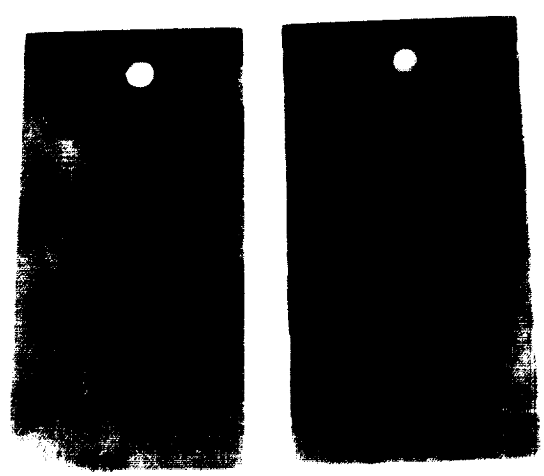


Figure 2. 4130 Steel With Cadmium Electrodeposit (a) With Dichromate Treatment and (b) Without Dichromate Treatment.

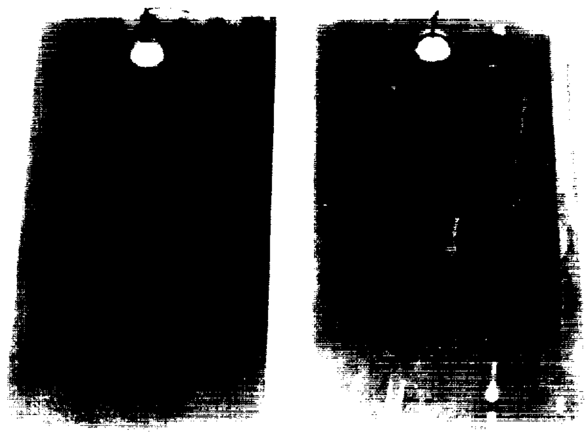


A) WITH DICHROMATE TREATMENT

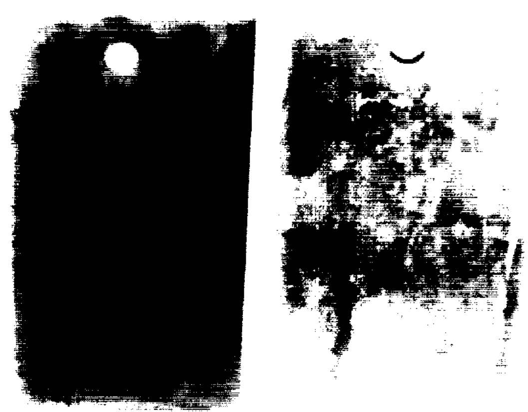


B) WITHOUT DICHROMATE TREATMENT

Figure 3. 4130 Steel With Zinc-Nickel Electrodeposit (a) With Dichromate Treatment and (b) Without Dichromate Treatment.

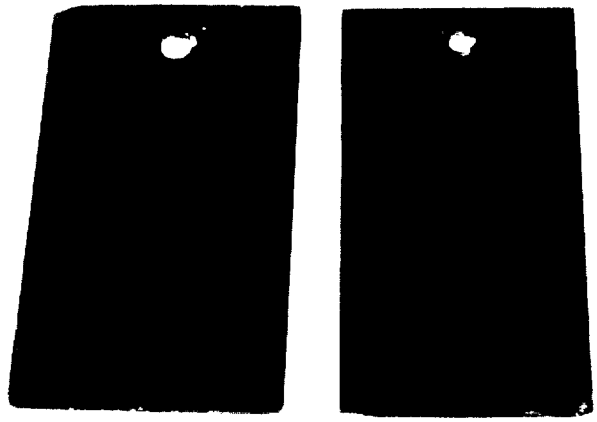


A) 96 HOURS OF SALT SPRAY EXPOSURE

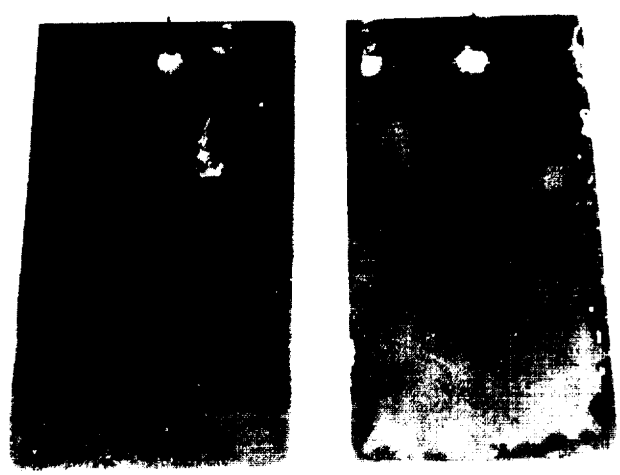


B) 240 HOURS OF SALT SPRAY EXPOSURE

Figure 4. 4130 Steel With Cadmium Electrodeposit (a) After 96 Hours of Salt Spray Exposure and (b) After 240 Hours of Salt Spray Exposure.



A) WITH DICHROMATE TREATMENT



B) WITHOUT DICHROMATE TREATMENT

Figure 5. 4130 Steel With Zinc-Nickel Electrodeposit After 96 Hours of Salt Spray Exposure (a) With Dichromate Treatment and (b) Without Dichromate Treatment.

A) WITH DICHROMATE TREATMENT

B) WITHOUT DICHROMATE TREATMENT

Figure 6. 4130 Steel With Zinc-Nickel Electrodeposit After 240 Hours of Salt Spray Exposure (a) With Dichromate Treatment and (b) Without Dichromate Treatment.

Table 1. Hydrogen Content of Bare 4130 Alloy Steel Versus Electrodeposited Zinc-Nickel on 4130 Alloy Steel.

METALLIC SURFACE	ZINC-NICKEL		BARE 4130 STEEL	
	SAMPLE 1	SAMPLE 2	SAMPLE 1	SAMPLE 2
No Heat Exposure	65.2	70.4	62.0	64.0
Average (ppm)	67.8		63.0	
(176.8C) 350 F 1 Hour	25.6	28.7	17.0	
Average (ppm)	27.15			
(176.8C) 350 F 3 Hours	19.3	21.1	10.0	
Average (ppm)	20.2			
(176.8C) 350 F 24 Hours	15.6	11.7	10.4	
Average (ppm)	13.65			

Table 2. Electrodeposited Cadmium and Zinc-Nickel Technical Data.

COATING	CADMIUM	ZINC-NICKEL
Melting Point	321.1 C (610 F)	419-600 C (786-1112 F)
Hardness	16-23 HB	132 Vickers$_{100}$
Thickness	Unlimited	Unlimited
Toxicity	(Extremely)	Less Toxic than Cadmium
Concentration	99.9% Cadmium	7-10% Nickel

REFERENCES

1. Zinc: Its Corrosion Resistance, Battelle Memorial Institute.
2. Metals Handbook, Volume 13, Corrosion.
3. Fontana and Green, Corrosion Engineering.
4. MIL-P-85748 Military Specification, Plating, Zinc-Nickel (Electrodeposited).

APPROVAL

ELECTRODEPOSITED ZINC-NICKEL AS AN ALTERNATIVE TO CADMIUM PLATING FOR AEROSPACE APPLICATION

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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